US010046504B2

(12) **United States Patent**
Rymann

(10) **Patent No.: US 10,046,504 B2**
(45) **Date of Patent: Aug. 14, 2018**

(54) **FLUID FLOW CONTROL DEVICE**

(71) Applicant: **NORGREN AG**, Balterswil (CH)

(72) Inventor: **Othmar Rymann**, Balterswil (CH)

(73) Assignee: **Norgren AG**, Balterswil (CH)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 32 days.

(21) Appl. No.: **15/032,226**

(22) PCT Filed: **Oct. 30, 2014**

(86) PCT No.: **PCT/EP2014/073310**
§ 371 (c)(1),
(2) Date: **Apr. 26, 2016**

(87) PCT Pub. No.: **WO2015/063202**
PCT Pub. Date: **May 7, 2015**

(65) **Prior Publication Data**

US 2016/0271857 A1 Sep. 22, 2016

Related U.S. Application Data

(60) Provisional application No. 61/897,734, filed on Oct. 30, 2013.

(51) **Int. Cl.**

F16K 5/10	(2006.01)
B29C 49/42	(2006.01)
F16K 3/32	(2006.01)
F16K 3/26	(2006.01)
F16K 5/04	(2006.01)
F16K 31/04	(2006.01)

(52) **U.S. Cl.**
CPC ***B29C 49/4289*** (2013.01); ***F16K 3/262*** (2013.01); ***F16K 3/32*** (2013.01); ***F16K 5/0407*** (2013.01); ***F16K 5/10*** (2013.01); ***F16K 31/041*** (2013.01)

(58) **Field of Classification Search**
CPC B29C 49/4289; F16K 31/041; F16K 5/10; F16K 5/0407; F16K 3/262; F16K 3/32; F16K 5/12; F16K 1/54
USPC 251/206–209, 129.11; 137/1
See application file for complete search history.

(56) **References Cited**

U.S. PATENT DOCUMENTS

679,247 A * 7/1901 Whiting B62D 5/097 137/625.24
792,928 A * 6/1905 Riess F16K 5/0605 126/292

(Continued)

FOREIGN PATENT DOCUMENTS

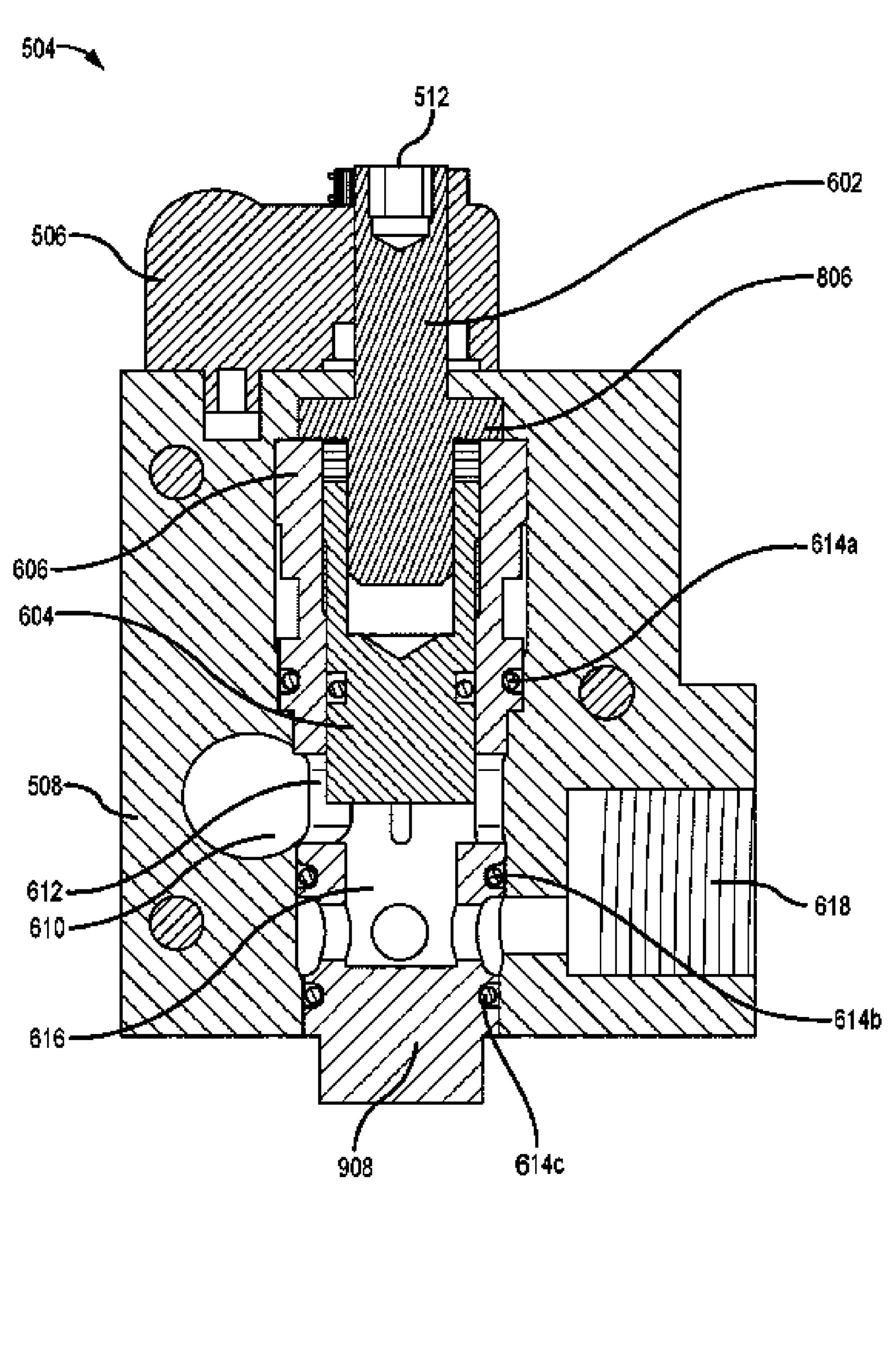
WO 2009135490 A2 11/2009
WO 2014199302 A2 12/2014

Primary Examiner — John Bastianelli
(74) *Attorney, Agent, or Firm* — The Ollila Law Group LLC

(57) **ABSTRACT**

The Application describes a throttle and a method for controlling a fluid flow via a throttle . The throttle includes an inlet (**618**) in communication with a pressurized gas source, an outlet (**610**) including a selected output orifice (612), and an orifice sleeve (**606**) including a plurality of output orifices (**612***a*, **612***b*, **612***c*, **612***d*) from which a selected output orifice (**612**) may be selected by rotating the orifice sleeve (**606**). The throttle may further include a piston (**604**) movable across a surface area of the selected output orifice (**612**), and a motor operable to move the piston (**604**) across the surface area of the selected output orifice (**612**).

10 Claims, 10 Drawing Sheets



(56) **References Cited**

U.S. PATENT DOCUMENTS

1,056,344	A *	3/1913	Lester	F16K 37/0016	137/556.6
2,750,929	A *	6/1956	Bronson	B64D 1/04	137/505.13
2,868,155	A *	1/1959	Phillips	F15B 7/00	116/269
3,047,015	A *	7/1962	Buck	F15B 11/04	137/614.17
3,298,396	A *	1/1967	Gressman	G05D 11/006	137/614
3,406,705	A *	10/1968	Meyer	F16K 3/243	137/207
3,558,100	A *	1/1971	Hulsey	F16K 5/0435	251/207
3,612,102	A *	10/1971	Hulsey	F16K 5/10	137/625.3
5,520,217	A *	5/1996	Grawunde	F15B 13/0435	137/625.63
6,808,162	B2 *	10/2004	Tranovich	F16K 5/0407	251/121

* cited by examiner

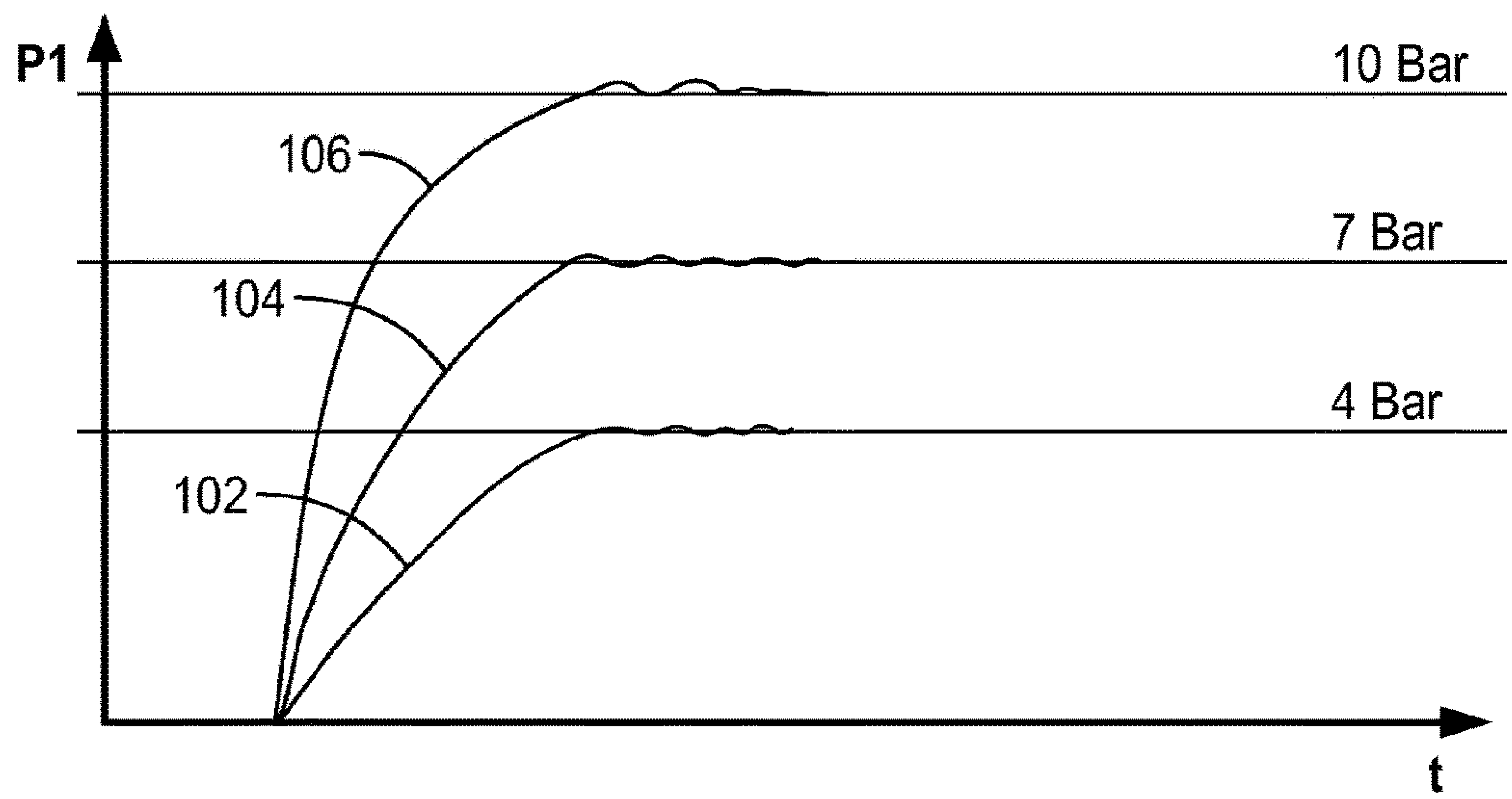


FIG. 1

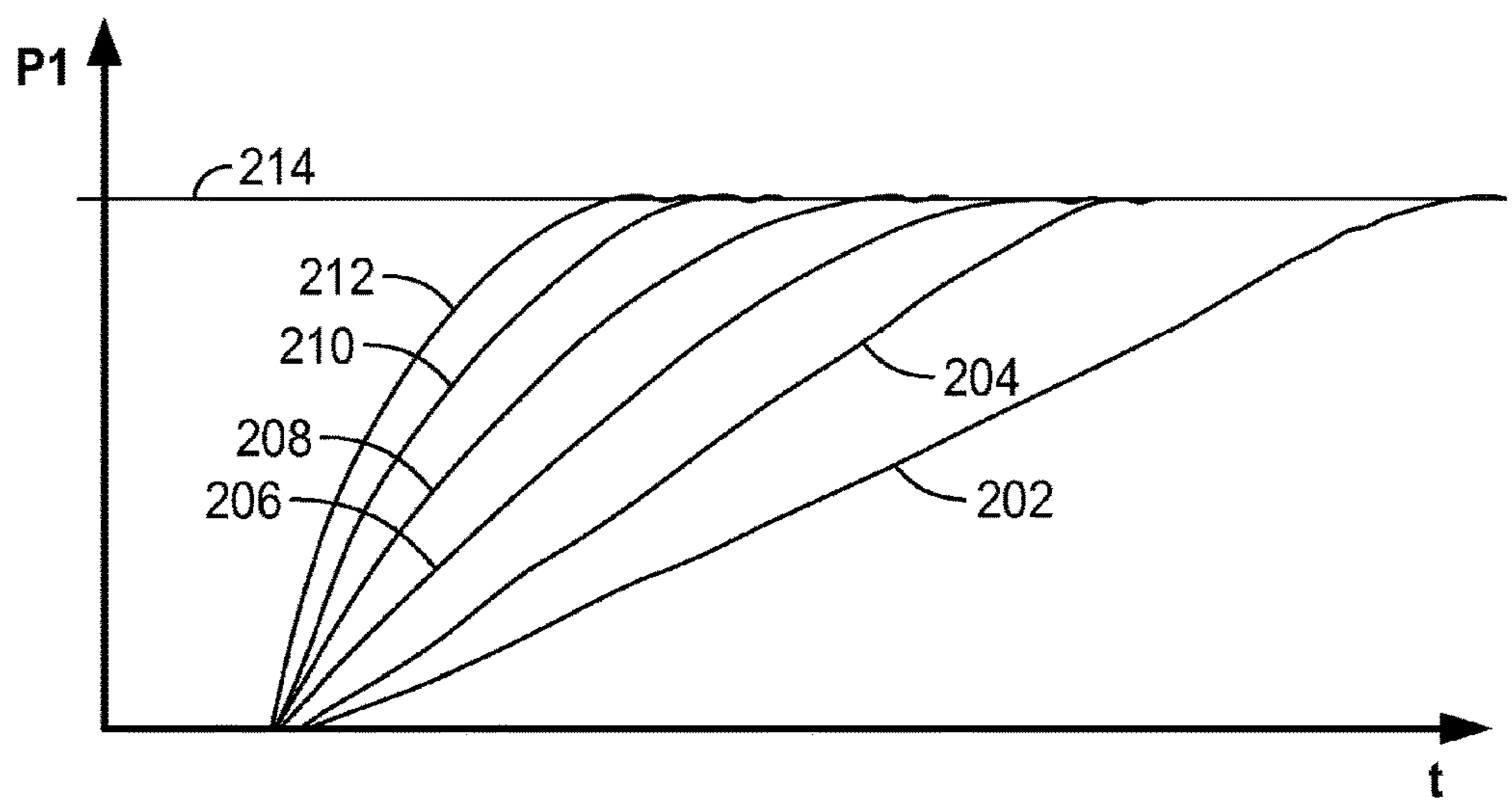


FIG. 2

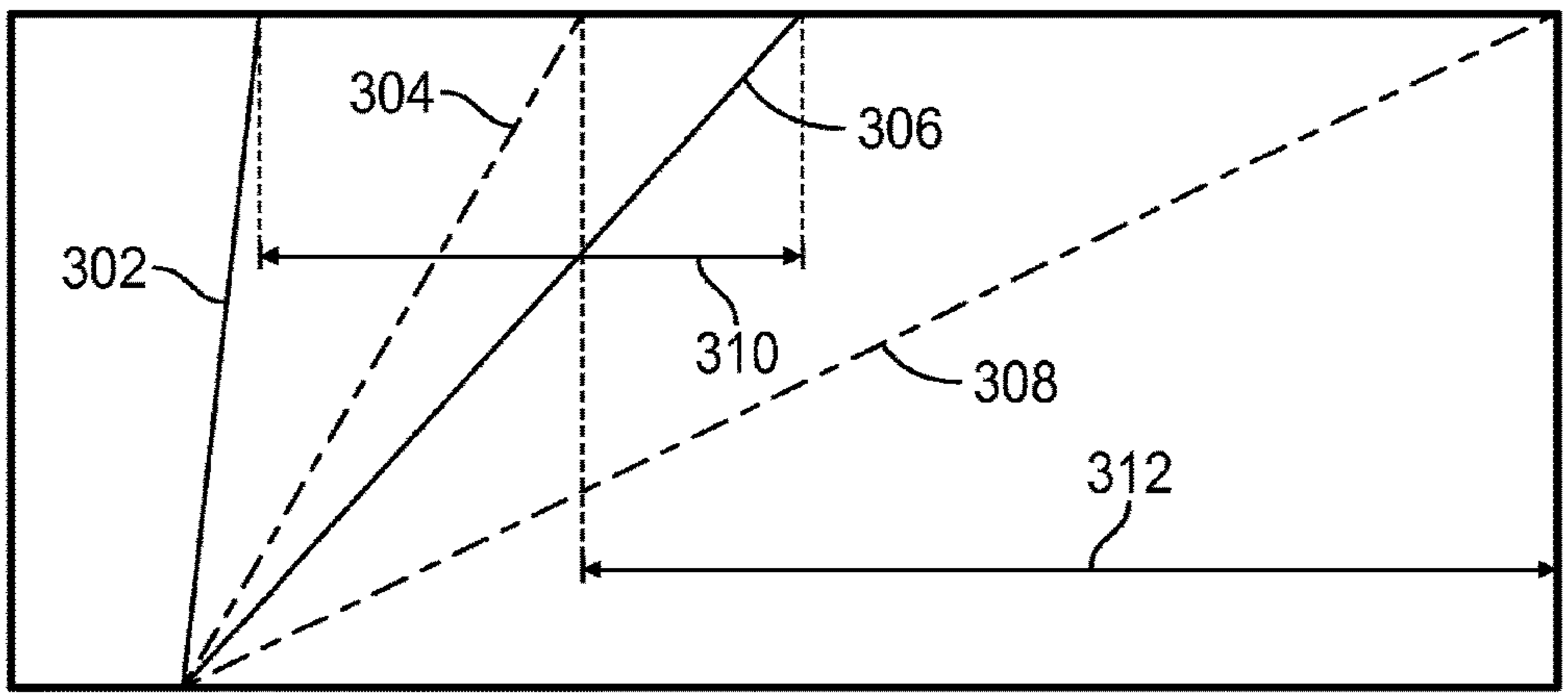


FIG. 3

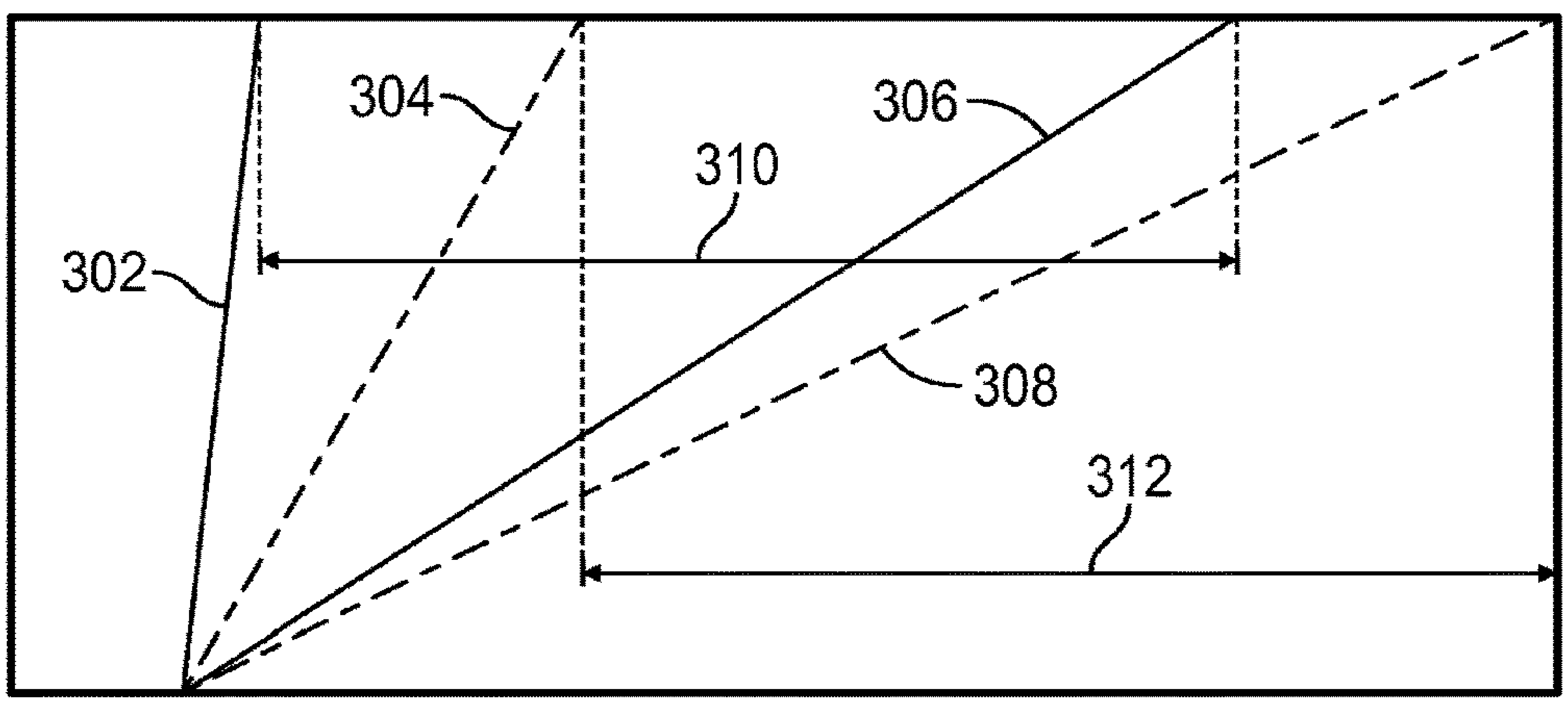


FIG. 4

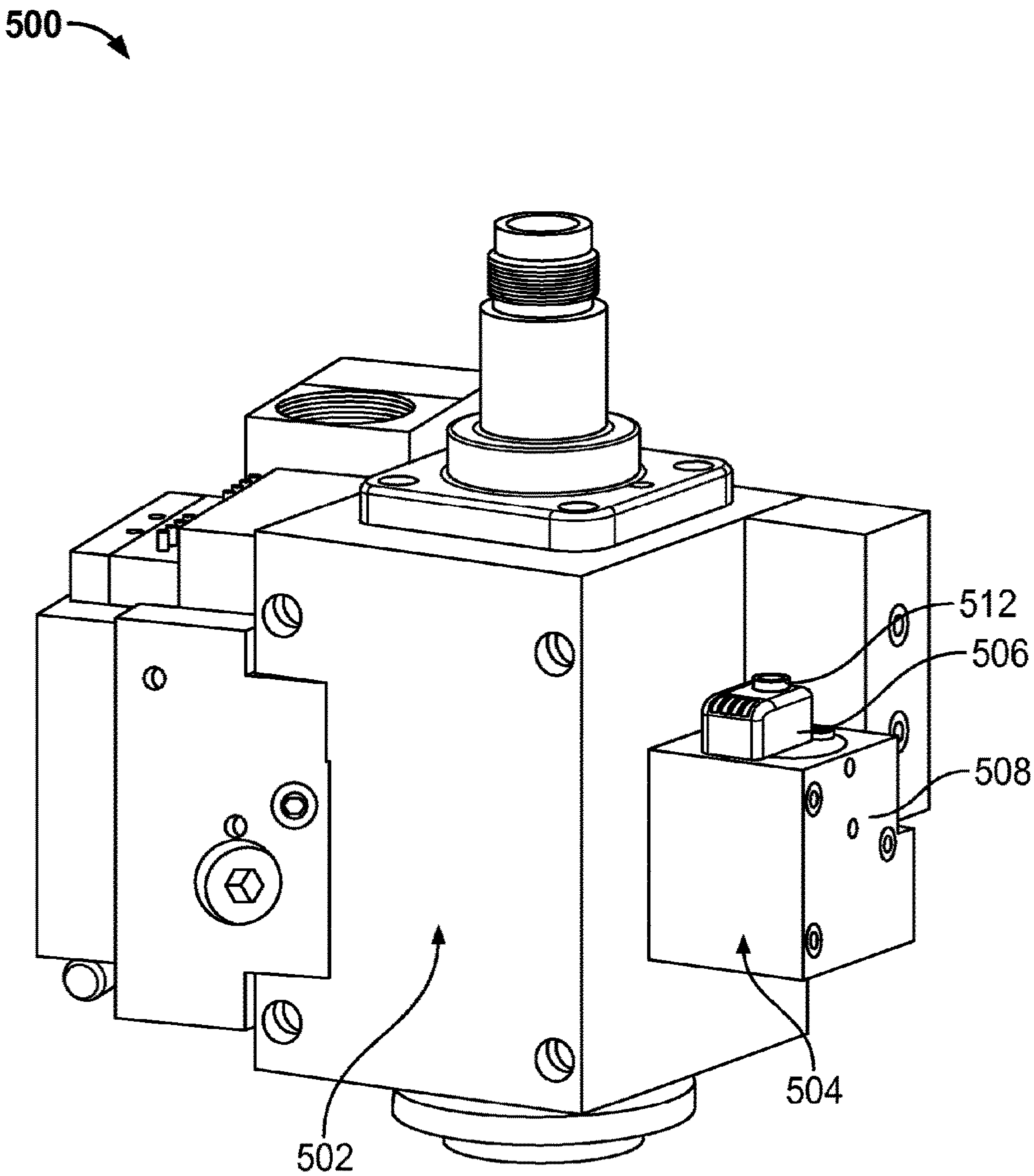


FIG. 5

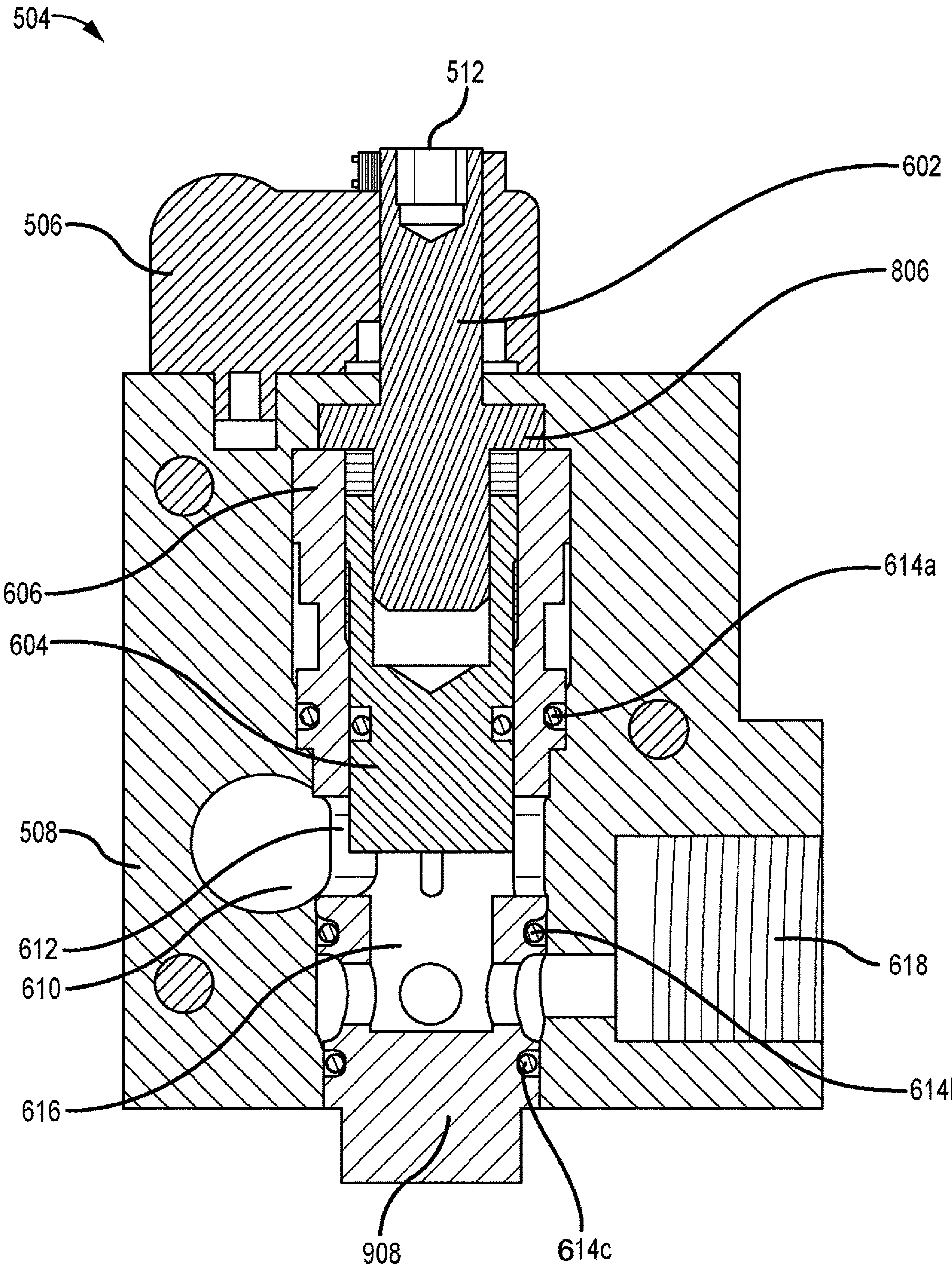

504
512
602
506
806
606
614a
604
508
618
612
610
616
614b
908
614c

FIG.6

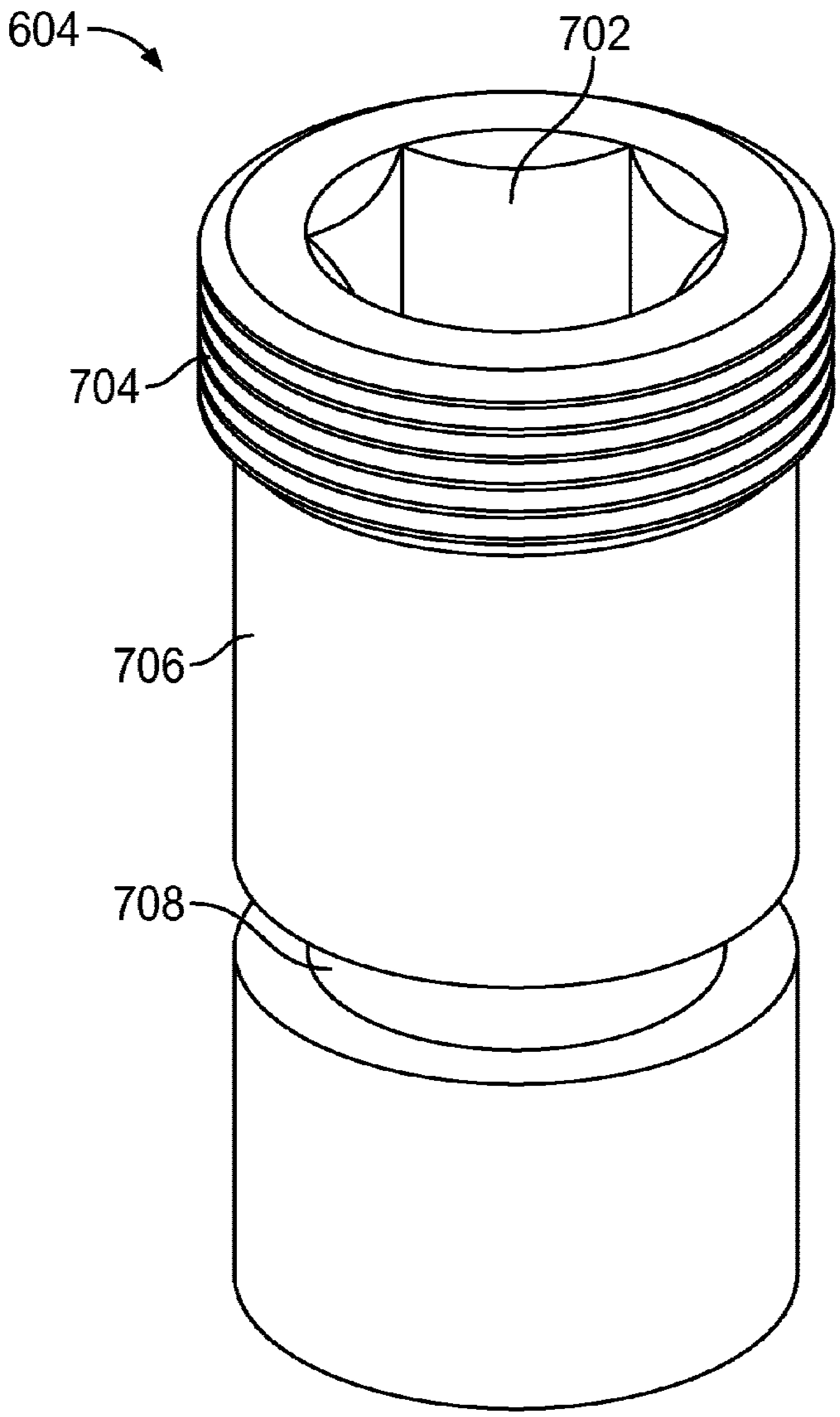


FIG. 7

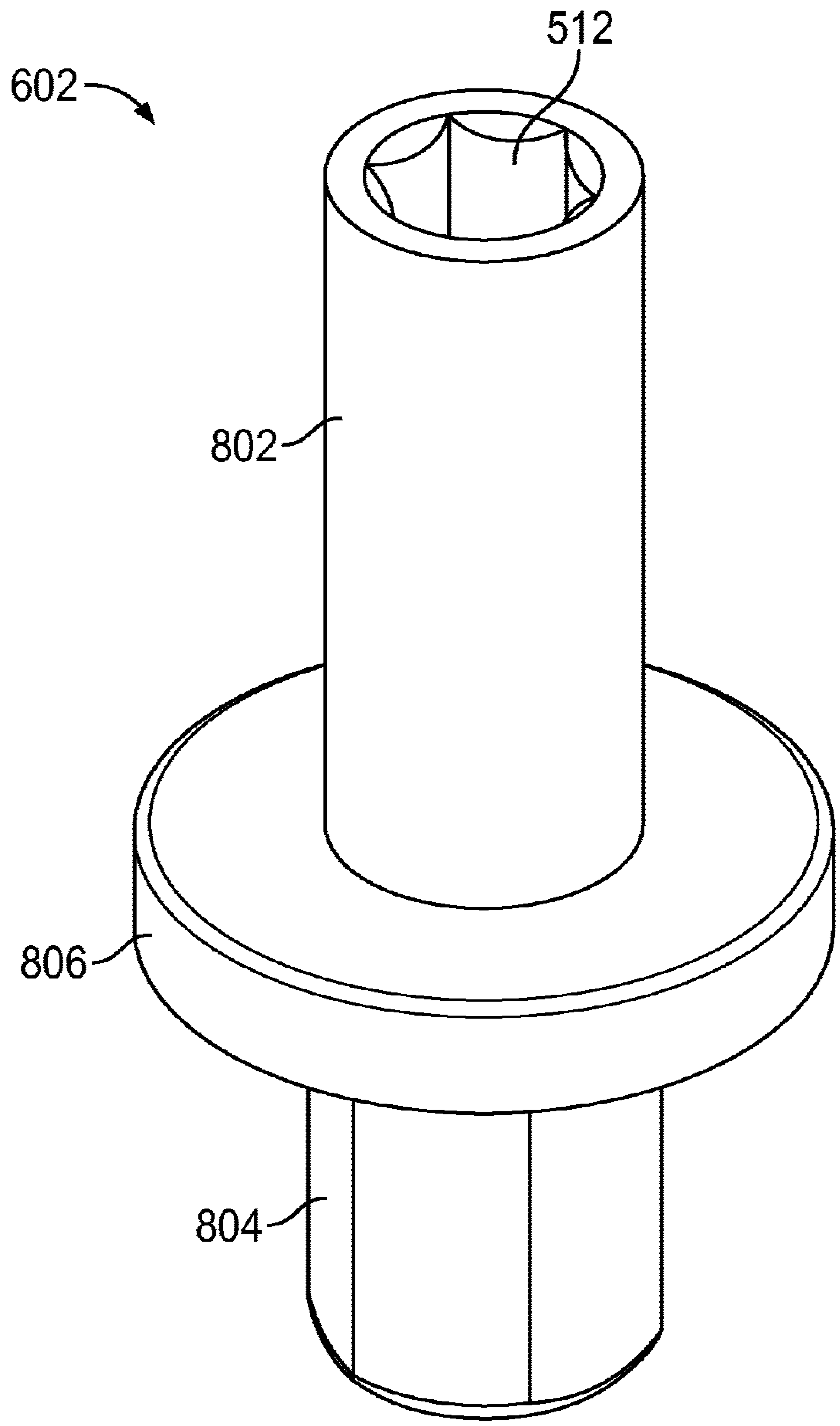


FIG. 8

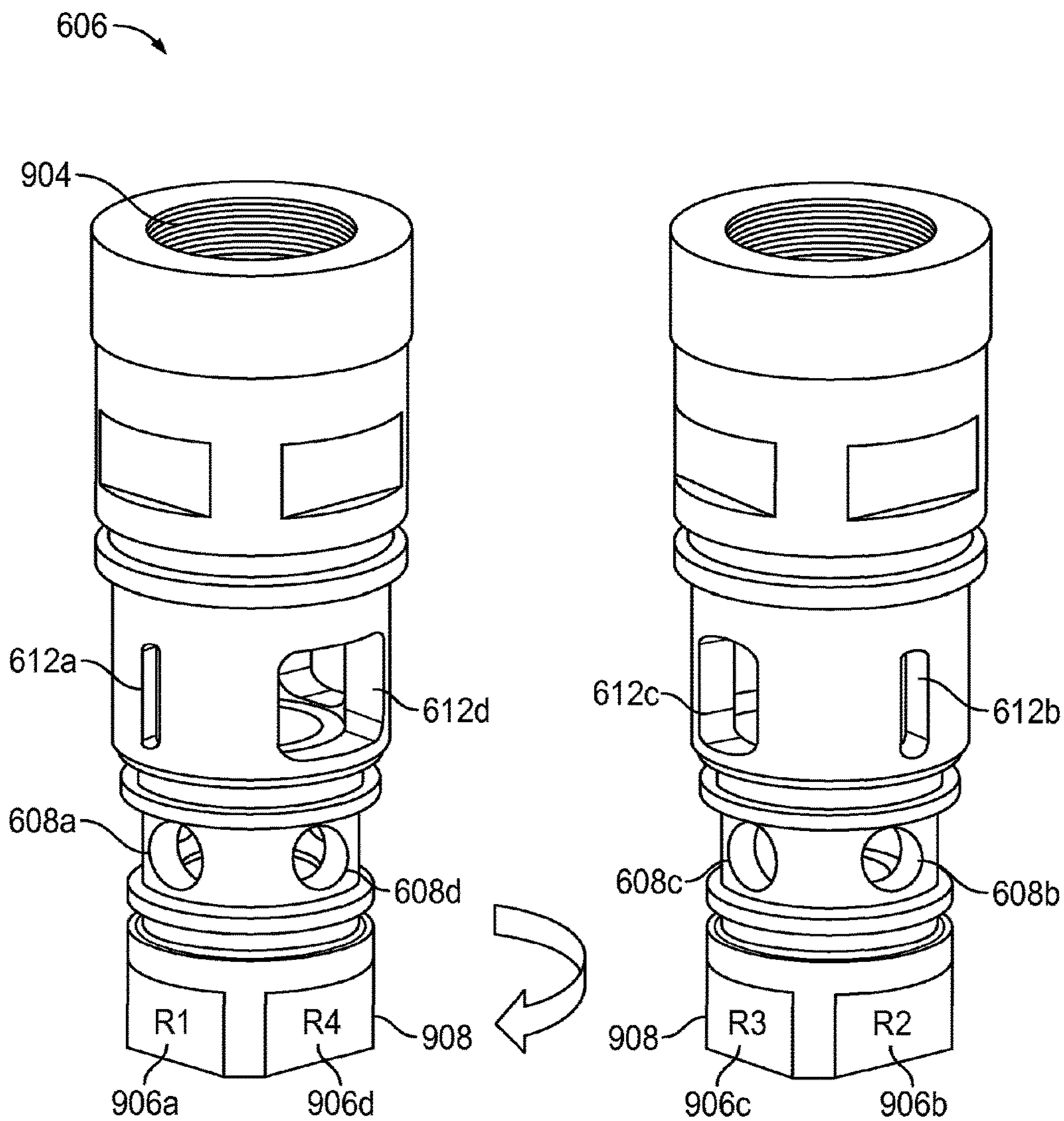

606
904
612a
612d
612c
612b
608a
608d
608c
608b
R1
R4
R3
R2
908
908
906a
906d
906c
906b

FIG. 9

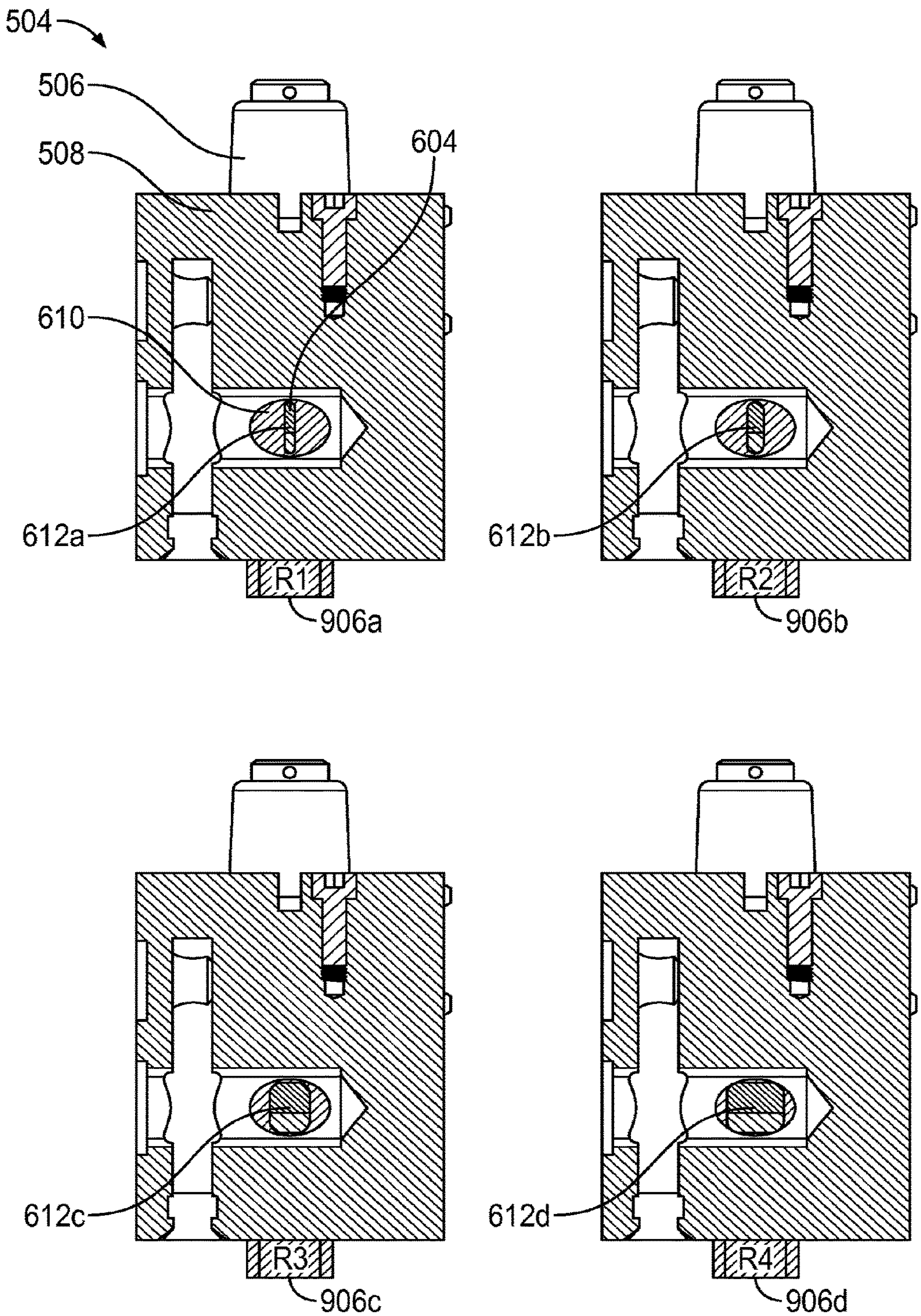

504
506
508
604
610
612a
R1
906a
612b
R2
906b
612c
R3
906c
612d
R4
906d

FIG. 10

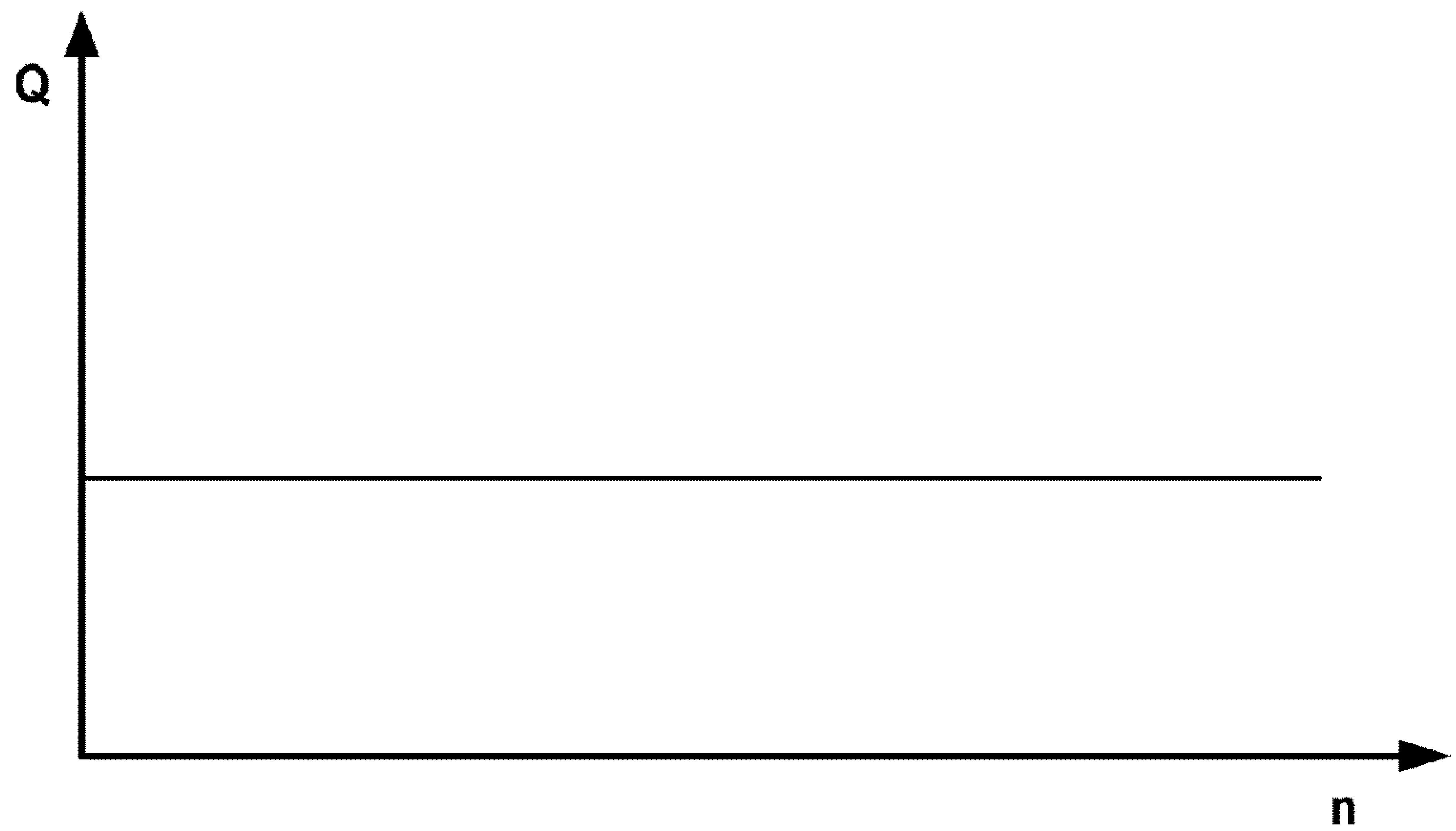


FIG. 11A

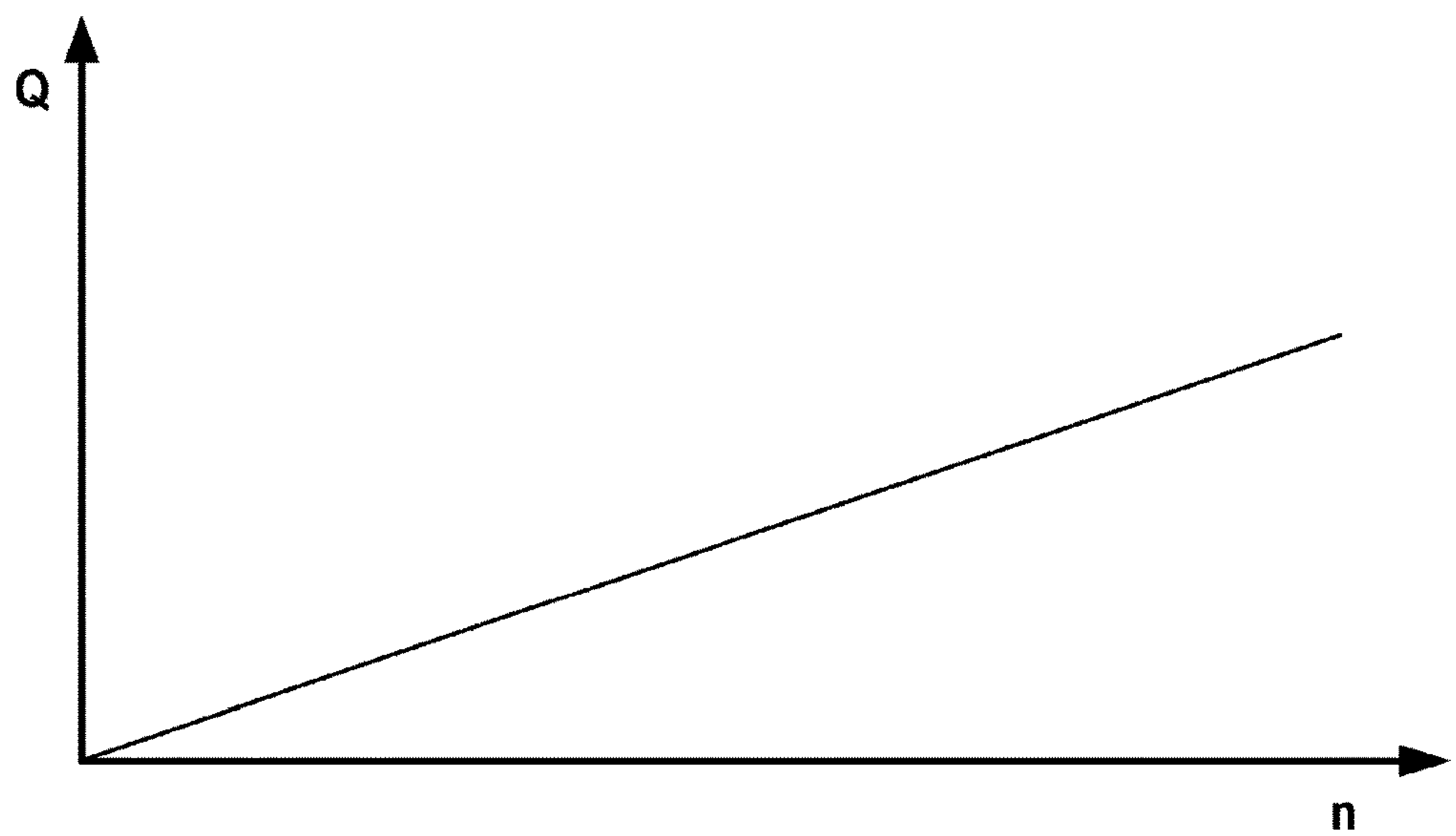


FIG. 11B

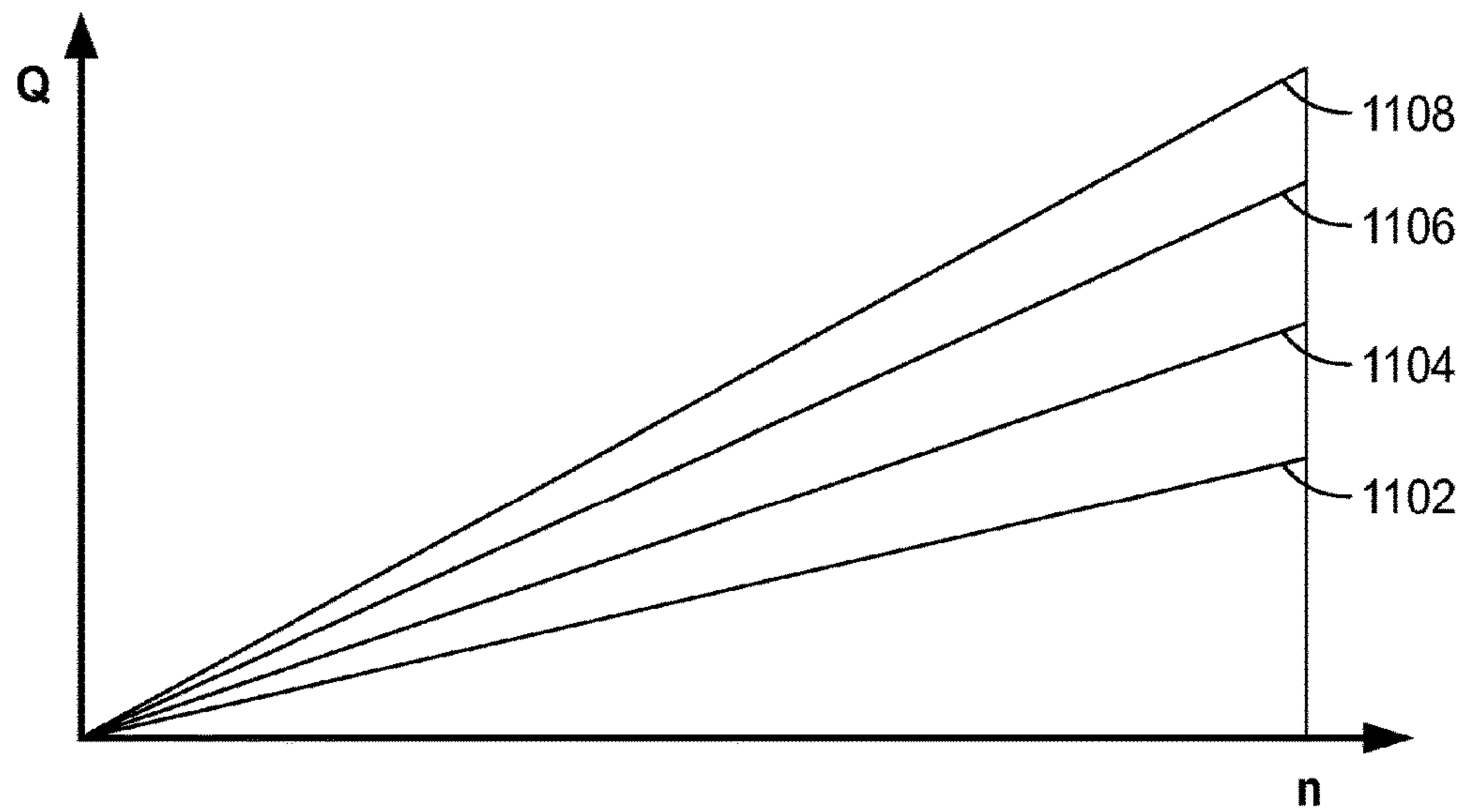


FIG. 11C

FLUID FLOW CONTROL DEVICE

TECHNICAL FIELD

The Application is related to the field of fluid flow control, and more particularly, to a throttle.

BACKGROUND OF THE APPLICATION

Blow-molding is a process for molding a preform part into a desired product. The preform is in the general shape of a tube with an opening at one end for the introduction of pressurized gas, typically air; however, other gases may be used. One specific type of blow-molding is stretch blow-molding (SBM). In typical SBM applications, both low and high-pressure gas is used to expand the preform into a mold cavity. The mold cavity comprises the outer shape of the desired product. SBM can be used in a wide variety of applications; however, one of the most widely used applications is in the production of Polyethylene terephthalate (PET) products, such as drinking bottles.

Typically, the SBM process uses a low-pressure fluid supply along with a stretch rod that is inserted into the preform to stretch the preform in a longitudinal direction and radially outward and then uses a high-pressure fluid supply to expand the preform into the mold cavity. The low-pressure fluid supply along with the stretch rod is typically referred to as a pre-blowing phase of the molding cycle. The high-pressure fluid supply that expands the preform into the mold cavity is typically referred to as the blowing phase of the molding cycle. The low-pressure and high-pressure fluid supplies can be controlled using blow-mold valves. The resulting product is generally hollow with an exterior shape conforming to the shape of the mold cavity. The gas in the preform is then exhausted through one or more exhaust valves. This process is repeated during each blow-molding cycle.

One of the more critical steps in the molding process occurs during the pre-blowing phase. During this phase, a pressure up to approximately 12 bar (174 psi) is provided to the preform while a stretch rod simultaneously extends the preform in a longitudinal direction. During the pre-blowing phase, there is an attempt to substantially uniformly distribute the material of the preform along the longitudinal length prior to expansion of the preform against the mold cavity. If the perform experiences a sudden jump in pressure during the pre-blowing phase, uniform distribution of the perform material may not be possible. In order to uniformly distribute the perform material, the pressure inside the preform must be carefully controlled.

Simply applying a pressurized gas source to a perform through a fixed orifice, aperture, or restrictor generates a steep, abrupt increase in pressure. Example pressure profiles **102**, **104**, and **106** are depicted in FIG. **1**. The x-axis in FIG. **1** represents time, and the y-axis represents pressure. Pressure profiles **102**, **104**, and **106** depict the increase in pressure inside a perform using a 4 bar, 7 bar, and 10 bar respective pressurized gas source. In each instance, pressure profiles **102**, **104**, and **106** approach equilibrium rapidly with the pressurized gas source in roughly the same amount of time.

It is possible to control the pressure profile inside a perform by including a throttle valve between the source of pressurized gas and the preform. For example, FIG. **2** depicts a series of pressure profiles generated during a blow-molding process in accordance with an embodiment. The x-axis in FIG. **2** represents time, and the y-axis represents pressure. Pressure profiles **202**, **204**, **206**, **208**, **210**, and **212** each increase at different rates to pressure level **214**, the pressure profiles being controlled via a variable throttle.

One design for a variable throttle includes an outlet orifice and a piston that may be moved to block a portion of the surface area of the outlet orifice to increase or reducing the fluid flow through the orifice. By controlling the fluid flow through the outlet orifice of the throttle, it is possible to more carefully control a pressure profile inside a preform.

In blow-molding manufacturing, it is desirable to use the same equipment with minimal adjustments to fabricate multiple bottle sizes. In operating a throttle to control a pressure profile inside a preform, a piston may be stepped or moved through a stroke profile that includes a start position, a distance to actuate, and a rate to move. If the piston can be stepped through the same stroke profile for a wide variety of products, the need to reconfigure the piston stroke during the equipment setup can be minimized. For example, a piston stroke profile may include ten rotary turns of a piston to move the piston from a nearly closed position wherein the piston covers 100% of the surface area of an orifice to a position where the rotary piston is open and covers 0% of the surface area of the orifice.

Typical blow-molding bottle sizes may vary in volume from 0.2 L to 3.0 L, providing a volume range factor of 3.0/0.2=15. Pre-blowing pressures typically range between 2 bar and 12 bar, however, providing a pressure range factor of 12/2=6. Because the volume range factor (15) and pressure range factor (6) are different, the resolution of a throttle with a single output orifice cannot provide adequate flow resolution to match the extreme range of bottle volumes from 0.2 L to 3.0 L. In other words, a throttle outlet orifice that is ideal for a 3.0 L bottle size, providing adequate flow resolution to provide a desired pressure profile when a piston is moved across the surface area of the outlet orifice, will not provide an adequate resolution for a bottle side of 0.2 L. In order to generate any of the pressure profiles depicted in FIG. **2** for a variety of bottle sizes, a manufacturer will need adequate pressure resolution for each bottle size being fabricated.

FIG. **3** depicts pressure profiles in accordance with an embodiment. FIG. **3** illustrates the difference in pressure resolution that occurs when blowing extreme bottle sizes using the same throttle orifice surface area and blow-molding valve. In FIG. **3**, the x-axis represents time when a perform is filling to a pre-blowing pressure level and the y-axis represents pressure inside a preform. Curves **302** and **306** represent the pressure inside a perform for a 0.2 L bottle, and curves **304** and **308** represent the pressure inside a perform for a 1.5 L bottle. In pressure profiles **302** and **304**, the piston is positioned so that the outlet orifice of the throttle is 100% open. In pressure profiles **306** and **308**, the piston is positioned so that the outlet orifice of the throttle covers 10% of the surface area of the orifice. As may be seen, the difference in time between when the 0.2 L bottle reaches the pre-blowing pressure level with each of the two piston positions is represented by the double-sided arrow **310**. The difference in time between when the 1.5 L bottle reaches the pre-blowing pressure level with each of the two piston positions is represented by the double-sided arrow **312**. Arrow **310** is shorter than arrow **312**, indicating that for the given outlet orifice, the 1.5 L bottle size has more pressure resolution than the 0.2 L bottle size. In other words, the pressure resolution of the blow-molding valve and throttle is dependent on the bottle size being blown.

FIG. **4** depicts further pressure profiles in accordance with an embodiment. FIG. **4** is similar to FIG. **3**, except that pressure profile **306**, the pressure profile for a 1.5 L bottle with 10% of the surface area of the outlet orifice of the throttle open, is less steep than in FIG. **3**. In FIG. **4**, arrows **310** and **312** are the same length, meaning that the 0.2 L bottle size has the same pressure resolution as the 1.5 L bottle size.

There is a need in the art for a throttle that is easy to configure and operate to provide resolution under a variety of conditions to finely control pressure. The present embodiments described below overcome these and other problems and an advance in the art is achieved.

SUMMARY OF THE APPLICATION

A throttle is provided according to an embodiment of the application. The throttle includes an inlet, an outlet, and an orifice sleeve. The inlet is in communication with a pressurized gas source. The outlet further includes a selected output orifice. The orifice sleeve further includes a plurality of output orifices. The selected output orifice may be selected from the plurality of output orifices by rotating the orifice sleeve.

A throttle is provided according to an embodiment of the application. The throttle includes an inlet, an outlet, a piston, a motor, and an orifice sleeve. The inlet is in communication with a pressurized gas source. The outlet further includes a selected output orifice. The piston is movable across a surface area of a selected output orifice. The motor is operable to move the piston across a surface area of the selected output orifice. The orifice sleeve further includes a plurality of output orifices. The selected output orifice may be selected from the plurality of output orifices by rotating the orifice sleeve.

A method is provided for controlling a fluid flow via a throttle including an inlet and an outlet. The method includes the step of rotating an orifice sleeve to select a selected outlet orifice. The orifice sleeve includes a plurality of output orifices from which the selected output orifice may be selected. The method further includes the step of applying a pressurized gas source to the inlet.

ASPECTS

In one embodiment of the throttle, the orifice sleeve further includes a plurality of tabs, each tab of the plurality of tabs usable to rotate the orifice sleeve.

In one embodiment of the throttle, each output orifice of the plurality of output orifices corresponds to a respective blow-molding bottle volume range.

In one embodiment of the throttle, the orifice sleeve further includes a plurality of inlet orifices, each inlet orifice of the plurality of inlet orifices corresponding to a respective outlet orifice of the plurality of outlet orifices.

In one embodiment of the throttle, the throttle further includes a piston movable to obstruct a portion of a surface area of the selected output orifice.

In one embodiment of the throttle, the throttle further includes a stepper motor operable to move the piston across the surface area of the selected output orifice.

In one embodiment of the throttle, the throttle further includes a servo motor operable to move the piston across the surface area of the selected output orifice.

In one embodiment of the method, the method further includes the step of moving a piston across a surface area of the selected output orifice.

In one embodiment of the method, moving the piston across the surface area of the selected output orifice includes operating a motor.

In one embodiment of the method, the selected output orifice corresponds to a range of blow-mold bottle volumes.

In one embodiment of the method, turning the rotary sleeve to select the selected output orifice includes selecting a tab from of a plurality of tabs, each tab of the plurality of tabs identifying an output orifice of the plurality of output orifices.

BRIEF DESCRIPTION OF THE DRAWINGS

The same reference number represents the same element on all drawings. It should be understood that the drawings are not necessarily to scale.

FIG. **1** depicts a series of pressure profiles in accordance with an embodiment.

FIG. **2** depicts a series of pressure profiles in accordance with an embodiment.

FIG. **3** depicts a series of pressure profiles in accordance with an embodiment.

FIG. **4** depicts a series of pressure profiles in accordance with an embodiment.

FIG. **5** depicts a perspective view of a blow-molding valve in accordance with an embodiment.

FIG. **6** depicts a cross-sectional view of a pressure throttle in accordance with an embodiment.

FIG. **7** depicts a perspective view of a piston in accordance with an embodiment.

FIG. **8** depicts a perspective view of a motor shaft in accordance with an embodiment.

FIG. **9** depicts perspective views of an orifice sleeve in accordance with an embodiment.

FIG. **10** depicts a side view of a pressure throttle in accordance with an embodiment.

FIG. **11***a* depicts a fluid flow profile in accordance with an embodiment.

FIG. **11***b* depicts a fluid flow profile in accordance with an embodiment.

FIG. **11***c* depicts a series fluid flow profiles in accordance with an embodiment.

DETAILED DESCRIPTION OF THE INVENTION

FIGS. **5**-**11***c* and the following description depict specific examples to teach those skilled in the art how to make and use the best mode of the invention. For the purpose of teaching inventive principles, some conventional aspects have been simplified or omitted. Those skilled in the art will appreciate variations from these examples that fall within the scope of the invention. Those skilled in the art will appreciate that the features described below can be combined in various ways to form multiple variations of the invention. As a result, the invention is not limited to the specific examples described below, but only by the claims and their equivalents.

FIG. **5** depicts a blow-molding valve **500** in accordance with an embodiment of the application. Blow-molding valve **500** includes a valve body **502**, a throttle **504**, a motor **506**, a throttle body **508**, and a shaft head **512**.

Blow-molding valve **500** may be used to control the flow of gas into a bottle being fabricated from a preform. For example, blow-molding valve **500** may be used to create any of the pressure profiles depicted in FIGS. **1**-**4**. Blow-molding valve **500** may be used during the pre-blowing stage, or any later stage of blow-molding a product. Those skilled in the art will understand that blow-molding valve **500** may be used in other fluid control applications as well.

Blow-molding valve **500** includes valve body **502**. Throttle **504** is coupled to body **502**. Throttle **504** includes an orifice (described below) that may be opened and closed to control the pressure of gas that flows out of blow-molding valve **500** into a product being fabricated. Throttle **504** includes throttle body **508**, and motor **506**. Motor **506** is operable to adjust the surface area of an outlet orifice inside throttle **504**, as will be described below. FIG. **5** further depicts shaft head **512**.

FIG. **6** depicts a cross-section of a throttle in accordance with an embodiment of the application. Throttle **504** includes motor **506**, throttle body **508**, a motor shaft **602** including shaft head **512**, a piston **604**, an orifice sleeve **606**, a fluid inlet **618**, a fluid outlet **610**, selected output orifice **612**, seals **614***a*, **614***b*, and **614***c*, and a fluid chamber **616**. Pressure throttle **504** may be used to control the flow of fluid, including gas, liquid, or a combination thereof, that enters fluid inlet **618** and exits fluid outlet **610**. While pressure throttle **504** is described within the context of a blow-molding application below, those skilled in the art will understand that pressure throttle **504** may be used in other fluid control applications as well.

It may be seen in FIG. **6** that motor shaft **602**, piston **604**, and orifice sleeve **606** are substantially enclosed inside of throttle body **508**. An example embodiment of motor shaft **602** is provide in FIG. **7**, an example embodiment of piston **604** is provided in FIG. **8**, and an example embodiment of orifice sleeve **606** is provided in FIG. **9**, as further described below.

Motor shaft **602** may be rotated with motor **506** or manually to displace piston **604** up and down with respect to orifice sleeve **606** during a blow-molding cycle. Piston **604** is be moved up or down with respect to the central axis of orifice sleeve **606** to vary the surface area of the selected outlet orifice **612**, thereby operating the throttle **504**.

Orifice sleeve **606** includes a hollowed out center portion that forms a substantially cylindrical inner surface stretching from threads **904** to a solid end **908**. A pressure chamber **616** is formed from the space that may be found inside orifice sleeve **606** between piston **604** and solid end **908**. In FIG. **6**, orifice sleeve **606** may be rotated to place pressure chamber **616** in communication with inlet **618** and outlet **610**.

Any of outlet orifices **612***a*, **612***b*, **612***c*, or **612***d* may be selected by rotating the orifice sleeve **606** until the selected outlet orifice faces fluid outlet **610**. Pressurized fluid may enter throttle **504** through inlet orifice **618**, pass through the pressure chamber **616**, and out of outlet orifice **612**. Piston **604** may move up or down to increase or reduce the surface area of the selected inlet orifice, thereby controlling the pressure of the fluid passing through throttle **504**.

Throttle **504** further includes seals **614***a*, **614***b*, and **614***c*. Seals **614***a*, **614***b*, and **614***c* may be o-rings or any other type of sealing member commonly known to those skilled in the art. Seals **614***a*, **614***b*, and **614***c* may prevent leaks from fluid chamber **616**.

FIG. **7** depicts an example embodiment of piston **604** in accordance with an embodiment. Piston **604** includes a hex head **702**, threads **704**, a shaft stem **706**, and an annular inset **708**. Shaft stem **706** defines the substantially cylindrical body of piston **604**. Piston **604** includes a section of male threads **704** that translate the rotation of piston **604** into linear piston **604** displacement in the axial direction. Piston **604** has a stroke along the longitudinal axis of orifice sleeve **606** that may be used to modulate the surface area of selected output orifice **612**. In an embodiment, piston **604** may have a stroke of 0-10 mm.

FIG. **8** depicts an example motor shaft **602** in accordance with an embodiment. Motor shaft **602** is substantially cylindrical, and includes shaft head **512**, a shaft stem **802**, a hex key **804** and an annular portion **806**. Hex key **804** is a male hexagon fitting that can fit securely in the female hex head **702** portion of piston **604**. When torque is applied to motor shaft **602** via shaft head **512** or shaft stem **802**, motor shaft **602** provides rotational force via hex key **804** to rotate piston **604**. Annular portion **806** is designed to secure motor shaft **602** inside throttle **504**. For example, it may be seen in FIG. **6** that annular portion **806** may be positioned between throttle body **508** and the top of orifice sleeve **606** within the throttle **504** assembly.

FIG. **9** depicts two perspective views of an example orifice sleeve **606** in accordance with an embodiment. Orifice sleeve **606** includes a substantially cylindrical exterior surface. At one end, orifice sleeve **606** is open and includes threads **904**, and at the other end, solid end **908**, orifice sleeve **606** is closed. Female threads **904** may couple to male piston threads **704** to position and align piston **604** inside of orifice sleeve **606**. As piston **604** is rotated inside orifice sleeve **606**, piston **604** may travel up and down via threads **904**.

Orifice sleeve **606** includes inlet orifices **608***a*, **608***b*, **608***c*, and **608***d*, outlet orifices **612***a*, **612***b*, **612***c*, and **612***d*, threads **904**, and tabs **906***a*, **906***b*, **906***c*, and **906***d*. Inlet orifice **608***a*, outlet orifice **612***a*, and tab **906***a* are aligned along the length of orifice sleeve **606**. Inlet orifice **608***b*, outlet orifice **612***b*, and tab **906***b* are aligned the length of orifice sleeve **606**. Inlet orifice **608***c*, outlet orifice **612***c*, and tab **906***c* are aligned along the length of orifice sleeve **606**. Inlet orifice **608***d*, outlet orifice **612***d*, and tab **906***d* are aligned along the length of orifice sleeve **606**. While example orifice sleeve **606** includes four inlet orifices and four outlet orifices, those skilled in the art will understand that any number of orifices may be used.

Orifice sleeve **606** includes tabs **906***a*, **906***b*, **906***c*, and **906***d* along its solid end **908**. Tabs **906***a*, **906***b*, **906***c*, and **906***d* are straight segments inset into orifice sleeve **606** at solid end **908** to create a cross section at solid end **908** a square with angled corners. The tabs **906***a*, **906***b*, **906***c*, and **906***d* may be used to easily grip orifice sleeve **606** to rotate orifice sleeve **606** about its center axis manually or via any automated means known to those skilled in the art. Rotating tabs **906***a*, **906***b*, **906***c*, and **906***d* rotates orifice sleeve **606** to expose the desired outlet orifices **612***a*, **612***b*, **612***c*, and **612***d* to fluid outlet **610**, thereby providing an additional level of adjustment to throttle **504**. Because tabs **906***a*, **906***b*, **906***c*, and **906***d* are non-cylindrical, their shapes may be further used to confirm proper alignment of the selected orifice **612** to the outlet **610**. In FIG. **9**, it may be seen that tabs **906***a*, **906***b*, **906***c*, and **906***d* include labels "R1," "R2," "R3," and "R4," which may allow a user to select the desired outlet orifice. Tabs **906***a*, **906***b*, **906***c*, and **906***d* make orifice sleeve **606** easy to reconfigure in a blast block that must accommodate different bottle sizes.

Outlet orifices **612***a*, **612***b*, **612***c*, and **612***d* are oriented so that their surface areas are perpendicular to the radial direction from the center of orifice sleeve **606**. In an embodiment, outlet orifices **612***a*, **612***b*, **612***c*, and **612***d* may be oblong and oriented so that their longest dimensions, or heights, are parallel to the longitudinal axis of the orifice sleeve **606**. When combined with the movement of piston **604** along the central axis of orifice sleeve **606**, this may advantageously allow for the greatest possible pressure resolution of throttle **504**. It may be seen in FIG. **9** that example outlet orifices **612***a*, **612***b*, **612***c*, and **612***d* each feature a different surface area, with the outlet orifices having substantially the same height dimension, but differing in the size of their widths. Advantageously, each outlet orifice **612***a*, **612***b*, **612***c*, and **612***d* may provide a maximum pressure resolution using the same piston **604** stroke profile. Those skilled in the art will understand, however, that any shape of outlet orifice may be used.

By designing each of the surface areas of outlet orifices **612***a*, **612***b*, **612***c*, and **612***d* to match a different range of bottle volumes, it is possible to provide adequate pressure resolution to blow-mold high quality bottles over a wide range of sizes.

FIG. **10** depicts four side views of throttle **504** in accordance with an embodiment. FIG. **10** depicts the fluid outlet **610** of throttle **504** with each of the four outlet orifices **612***a*, **612***b*, **612***c*, and **612***d* selected as selected output orifice **612**. In the example of FIGS. **9** and **10**, the surface area of the fluid orifices increase from outlet orifice **612***a* to **612***d*, with **612***d* being the largest. While each of outlet orifices **612***a*, **612***b*, **612***c*, and **612***d* have substantially the same height along the longitudinal dimension of orifice sleeve **606**, the outlet orifices vary in width. In each of the depictions, piston **604** is depicted in the same longitudinal position. Advantageously, it may be seen that turning orifice sleeve **606** allows for a quick configuration of selected output orifice **612**.

FIGS. **11***a*, **11***b*, and **11***c* depict fluid flow Q through outlet orifices. Flow Q is a function of outlet orifice area, outlet orifice geometry, and the differential pressure on either side of the outlet surface orifice. In FIGS. **11***a*, **11***b*, and **11***c*, the flow Q is represented on the y-axis against piston position n on the x-axis. Differential pressure and geometry are held constant in FIGS. **11***a*, **11***b*, and **11***c*, so that flow Q is only a function of outlet orifice surface area.

FIG. **11***a* depicts a fluid flow Q through a single fixed orifice. FIG. **11***a* depicts the simple scenario of a single output orifice with a piston position n that does not vary. Fluid flow Q is constant under the conditions depicted in FIG. **11***a*. Using the fluid flow Q depicted in FIG. **11***a*, it may be possible to generate the pressure profiles **102**, **104**, and **106** depicted in FIG. **1**.

FIG. **11***b* depicts a linear fluid flow Q through a single orifice with a moving piston. The surface area of the single orifice is varied at a constant pace using the moving piston to create a linear fluid flow Q. Using the fluid flow Q depicted in FIG. **11***b*, it may be possible to generate the pressure profiles **202**, **204**, **206**, **208**, **210**, and **212** depicted in FIG. **2**.

FIG. **11***c* depicts a multi-linear fluid flow Q through multiple orifices using a moving piston. FIG. **11***c* depicts example multi-linear fluid flows Q, including fluid flow profiles **1102**, **1104**, **1106**, and **1108**. Each fluid flow profile **1102**, **1104**, **1106**, and **1108** represents the fluid flow through a different output orifice **612***a*, **612***b*, **612***c*, or **612***d* while the surface area is varied at a constant rate using piston **604**. For example, outlet orifice **612***a* may generate fluid flow profile **1102**, outlet orifice **612***b* may generate fluid flow profile **1104**, outlet orifice **612***c* may generate fluid flow profile **1106**, and outlet orifice **612***d* may generate fluid flow profile **1108**.

Each fluid flow profile **1102**, **1104**, **1106**, and **1108** is generated using the same piston stroke profile. For example, piston **604** may have a stroke of 10 mm. When n=0, each outlet orifice **612***a*, **612***b*, **612***c*, or **612***d* is completely obstructed so that its respective surface area is 0% open and there is no flow Q. As n increases to the right, however, the percentage of surface area open increases, and flow Q also increases. Because each outlet orifice **612***a*, **612***b*, **612***c*, or **612***d* has a different respective width, however, a similar piston position n produces a different respective flows Q.

In embodiments, motor **506** may move piston **604** at different rates or with different degrees of precision to custom-tailor a fluid flow Q or pressure profile. For example, motor **506** may be a stepper motor able to rotate piston **604** with a resolution of 0.01 of a turn. If the stroke length is 10 turns, each fluid flow profile **1102**, **1104**, **1106**, and **1108** may have a resolution of **1000** piston positions n. With the four ranges provided by the four outlet orifice **612***a*, **612***b*, **612***c*, or **612***d* of orifice sleeve **606**, throttle **504** may offer **4000** total combinations of outlet orifice and piston position.

In a further example, motor **506** may be an electric servomotor able to rotate piston **604** with a resolution of 0.0025 of a turn. With a stroke length of 10 turns, each fluid flow profile **1102**, **1104**, **1106**, and **1108** may have a resolution of 4000 piston positions n with the four ranges provided by the four outlet orifice **612***a*, **612***b*, **612***c*, or **612***d* of orifice sleeve **606**, throttle **504** may offer 16000 total combinations of outlet orifice and piston position. These examples are not intended to be limiting however, as those in the art will understand other piston actuation mechanisms and stroke profiles also possible.

Advantageously, using the fluid flow profiles **1102**, **1104**, **1106**, and **1108** depicted in FIG. **11***c*, it may be possible to generate the pressure profiles **202**, **204**, **206**, **208**, **210**, and **212** depicted in FIG. **2** for a wide range of blow-molding products and bottle volumes. The increased pressure control resolution may enable robust, repeatable results when blow-molding bottles having extreme differences in volumes. For example, it may be possible to utilize outlet orifice **612***a* to blow-mold a high quality bottle with a volume range of 0-0.75 L, to use outlet orifice **612***b* to blow-mold a high quality bottle with a volume range of 0.75 L-1.5 L, to use outlet orifice **612***c* to blow-mold a high quality bottle with a volume range of 1.5 L-2.25 L, and to use outlet orifice **612***d* to blow-mold a high quality bottle with a volume range of 02.25 L-3.0L.

The detailed descriptions of the above embodiments are not exhaustive descriptions of all embodiments contemplated by the inventors to be within the scope of the application. Indeed, persons skilled in the art will recognize that certain elements of the above-described embodiments may variously be combined or eliminated to create further embodiments, and such further embodiments fall within the scope and teachings of the application. It will also be apparent to those of ordinary skill in the art that the above-described embodiments may be combined in whole or in part to create additional embodiments within the scope and teachings of the application.

Thus, although specific embodiments of the application and examples are described herein for illustrative purposes, various equivalent modifications are possible within the scope of the application, as those skilled in the relevant art will recognize. The teachings provided herein can be applied to other devices and method, and not just to the embodiments described above and shown in the accompanying figures. Accordingly, the scope of the application should be determined from the claims.

I claim:

1. Method of controlling a fluid flow via a throttle including an inlet and an outlet, the method comprising the steps of:

rotating an orifice sleeve to select a selectable output orifice, wherein the orifice sleeve includes a plurality of outlet orifices from which the selectable output orifice may be selected, the orifice sleeve including at least one input orifice and each outlet orifice of the plurality of outlet orifices having a different surface area

moving a piston across a surface area of the selected output orifice to vary the surface area of the selected output orifice by operating a motor; and

applying a pressurized gas source to the inlet.

2. The method of claim **1**, wherein the selectable output orifice corresponds to a range of blow-mold bottle volumes.

3. The method of claim **1**, wherein turning the rotary sleeve to select the selectable output orifice includes selecting a tab from of a plurality of tabs, each tab of the plurality of tabs identifying an outlet orifice of the plurality of outlet orifices.

4. A throttle comprising:

an inlet (**618**) in communication with a pressurized gas source;

an outlet (**610**) including a selectable output orifice (**612**);

a piston (**604**) movable across a surface area of a selectable output orifice (**612**);

a motor (**506**) operable to move the piston (**604**) across a surface area of the selectable output orifice (**612**); and

an orifice sleeve (**606**) including a plurality of outlet orifices (**612***a*, **612***b*, **612***c*, **612***d*) and at least one input orifice, each outlet orifice of the plurality of outlet orifices having a different surface area, wherein the selectable output orifice (**612**) may be selected from the plurality of outlet orifices (**612***a*, **612***b*, **612***c*, **612***d*) by rotating the orifice sleeve (**606**).

5. The throttle of claim **4**, wherein the orifice sleeve (**606**) further includes a plurality of tabs (**906***a*, **906***b*, **906***c*, **906***d*), each tab of the plurality of tabs (**906***a*, **906***b*, **906***c*, **906***d*) identifying an outlet orifice of the plurality of outlet orifices (**612***a*, **612***b*, **612***c*, **612***d*).

6. The throttle of claim **4**, wherein the orifice sleeve (**606**) further includes a plurality of tabs (**906***a*, **906***b*, **906***c*, **906***d*) usable to rotate the orifice sleeve (**606**).

7. The throttle of claim **4**, wherein the orifice sleeve (**606**) further includes a plurality of inlet orifices (**608***a*, **608***b*, **608***c*, **608***d*), each inlet orifice of the plurality of inlet orifices (**608***a*, **608***b*, **608***c*, **608***d*) corresponding to a respective outlet orifice of the plurality of outlet orifices.

8. The throttle of claim **4**, wherein the motor (**506**) is a stepper motor.

9. The throttle of claim **4**, wherein the motor (**506**) is a servo motor.

10. The throttle of claim **4**, wherein each outlet orifice of the plurality of outlet orifices (**612***a*, **612***b*, **612***c*, **612***d*) corresponds to a respective blow-molding bottle volume range.

* * * * *